

Director's Review

LBNL Physics Division

November 8 - 9, 2005

Theory Group

Presented by M. Chanowitz

- Overview**
- Research**
- Supplementary Material**

- Theory Group research spans the full range of HEP:
 - Standard Model
 - *per se* and as essential precursor to new physics.
 - Beyond SM model-building
 - SUSY, extra-d, alternatives to Higgs,...
 - Cosmology/Particle-Astrophysics
 - models *of* and constraints *from*
 - String Theory
 - mathematical structure and attempts to connect with observation
- Strong coupling to Phys. Div. expt'l program and to the overall US HEP program.
 - Support of ongoing program
 - Participation in planning of future program

Lab & Campus function as single unified group:

- Postdocs
- Students
- Visitor's program
- Seminars
 - Four weekly group seminars



utilizing pooled resources:

- LBNL Physics Division
- UCB NSF theory grants
- Campus-based Center for Theoretical Physics (CTP)
 - UCB endowment (\$1M “seed”)
 - 10 years ops support from LBNL & UCB

Staff

LBNL Senior Staff: Barnett (PDG/ATLAS), Cahn (BABAR),
Chanowitz*, Hinchliffe (ATLAS), *Ligeti* (11/04)

LBNL Division Fellow: *Bauer* (9/05)

UCB Faculty: Aganagic (9/04), Bousso (1/04), Gaillard,
Ganor, Hall#, Halpern, Horava, Murayama+,
Nomura (11/03), Suzuki

Retired: Bardakci, Chew, Jackson, Mandelstam,
Stapp, Zumino

Administrative Staff: Diaz (75%), Henderson (50%)

*Group Leader, #CTP Head, +NSF Lead PI

Postdocs

		<u>Support</u>	<u>From</u>
Dyson	(1/06 – Chancellor's Fellow)	UCB	Stanford
Gimon	(5 year fellow)	CTP	IAS
Fox		LBL	UCSC
Freivogel		CTP	Stanford
Pappuci		NSF	Pisa
Perez	(Ligeti OJI)	LBL	Weizmann
Schwartz		CTP	Harvard
Watari	(Miller fellow)	UCB	Tokyo U

Departed Fall 06:

Hubeny & Rangamani —> faculty @ Durham, UK

Tatar —> 5-yr PPARC fellow @ Imperial College

Mitra —> high finance

Theory Group impact on HEP faculty staffing

Since 1993, all but one Theory Group particle physics postdoc went on to a faculty position in HEP theory:

Zacharia Chacko (Arizona)
Yasunori Nomura (Berkeley)
Gustavo Burdman (Sao Paolo)
Walter Goldberger (Yale)
Maxim Perelstein (Cornell)
Christopher Kolda (Notre Dame)
Mihir Worah (left field)
John Terning (Davis)
Christophe Grojean (Saclay)

Csaba Csaki (Cornell)
Takeo Moroi (Tohoku)
Jonathan Feng (Irvine)
Chris Carone (Williams and Mary)
Hitoshi Murayama (Berkeley)
Markus Luty (Maryland)
John March-Russell (Oxford)
Uri Sarid (Notre Dame → software startup)
Raman Sundrum (John Hopkins)

Students

- Support GSRA's for 2 years
- Currently 6 supported GSRA's (5 by LBNL)

Current Roster

D. Butter (MKG)	S. Oliver (LH)
D. Chiou (OG)	C. Park (MKG)
B Feldstein (LH)	A. Pasqua (BZ)
J. Gill (OG)	D. Poland (YN)
B. Kain (MKG)	M. Randsdorp (MKG)
C. Keeler (PH)	P. Shepard (PH)
B. Kim (OG)	F. Tackman (ZL)
A. Mints (RB)	B. Tweedie (YN)
	D. Vasilyuk (OG)

'05 graduates:

Harnik (HM) → SLAC
Larson (HM) → Harvard

Career data for graduates, 1980 - , in supplementary material

Visitors Program

Provides support for 1 – 3 week visits

- Supports joint research with group members
- In recent years funded mostly from CTP
- Has proven to be very worthwhile

FY 05 visitors:

R. Barbieri	Pisa	S. Mantry	MIT
P. Batra	ANL	G. Marandella	LANL
L. Baulieu	Univ. Pierre et Mari Curie	A. Nicolis	Harvard
G. Burdman	U. Sao Paulo	N. Obers	Niels Bohr
Z. Chacko	U. Arizona	T. Okuda	UCSB
M. Cirelli	Yale	T. Okui	Boston Univ.
R. Contino	Johh Hopkins Univ.	M. Parikh	Columbia Univ.
H. Goldberg	Northeastern Univ.	D. Pirjol	MIT
J. Hubisz	Cornell Univ.	M. Schulz	Cal Tech.
A. Karch	U. Washington	E. Sharpe	Univ. of Utah
R. Kitano	IAS	T. Takayangi	Harvard
A. Kleinschmidt	Max Planck	H. Verlinde	Princeton
B. Kol	Hebrew Univ.	J. Wells	Univ. of Michigan
G. Kribs	IAS	L. Wolfenstein	Carnegie-Mellon
H. Liu	MIT	T. Yamashita	Kyoto Univ.

Visiting Fellows

Self-supported long-term visitors (1 - 2 years),
typically supported by foreign fellowships.

B. Cerchiai

Italian fellowship

R. Enberg

Swedish fellowship

S. Ferrandis

Spanish fellowship

M. Quiroz

Mexican fellowship

Sabbatical K. Rajagopal, MIT (joint with Nucl. Sci. Div.)

Outlook

LBNL & UCB both on track, despite tight budgets

LBNL: recovering from defections to expt'l groups

- *Ligeti* —> Sr Staff (first since Cahn & Hinchliffe, ~1983)
- New Div Fellow: *C. Bauer*
- Another Div Fellow search planned for ~ 08.
- Renovation of theory area expected this year

UCB

- 3 recent asst profs: Aganagic, Bousso, Nomura
- Leconte renovation on schedule for Xmas 06
- CTP support assured for 10 years by LDRD/Phys Div/UCB

Campus & lab have unusually close & productive relationship.
Center of gravity could shift downhill after Leconte renovation.



Important to maintain vitality of LBNL theory,
as the existing plan will do.

Theory Group: broad range of research

E.g.,

- Work closely connected to experiment
 - heavy flavor physics
 - good ol' hadron physics*
 - signals of new physics @ LHC*, NLC
 - precision electroweak constraints on new physics*
 - neutrino masses/mixing +...
- “BSM” model building
 - dark matter signal @ CDMS & LHC*
 - resolving the “LEP paradox” @ LHC *
 - extra-dimensional models of EWSB +...
- String theory
 - possible astrophysical implications of string theory
 - holographic principle
 - d-branes in background fields & nonlocal field theory +...

* Discussed below

Some Examples

- Chiral suppressed scalar glueball decay
(Doors will be locked during this portion of the presentation)
- LSP-Dark matter signal at CDMS & LHC
- LEP Paradox @ LHC
- Precision EW: reading the tea leaves with a light top

Chiral Suppressed Scalar Glueball Decay

Glueballs: key prediction of QCD

MC PRL, 95, 172001, 05

– mix with & not easily distinguished from $\bar{q}q$

Properties {
Extra states, beyond $q\bar{q}$
Sticky: $\psi \rightarrow \gamma G / G \rightarrow \gamma\gamma \gg 1$
 $SU(3)_{\text{Flavor}}$ singlets $\Rightarrow SU(3)_{\text{Flavor}}$ symmetric decays

BUT for $J^{PC}=0^{++}$ ground state, chiral invariance implies big $SU(3)_{\text{Flavor}}$ breaking:

$$\Gamma(G_0 \rightarrow \bar{q}q) \propto m_q^2$$

- Leading order: $\Gamma(G_0 \rightarrow \bar{q}q) = \frac{16\pi}{3} \alpha_s^2 f_0^2 m_q^2 M_G \beta \log^2 \frac{1+\beta}{1-\beta}$
- Physical argument: *like* $\pi \rightarrow \mu\nu$, $e\nu$
- Verified to all orders in perturbation theory

$$\longrightarrow \Gamma(G_0 \rightarrow \bar{s}s) \gg \Gamma(G_0 \rightarrow \bar{u}u + \bar{d}d)$$

Away from gq IR singularities, $G_0 \rightarrow \bar{q}qg$ is $SU(3)_{\text{Flavor}}$ symmetric
(unlike $\pi \rightarrow \mu\nu\gamma$, $e\nu\gamma$)

Experimental Implications

- Expect $\Gamma(G_0 \rightarrow \bar{K}K) >> \Gamma(G_0 \rightarrow \pi\pi)$
 - consistent with quenched LGT result Weingarten et al., 1995
- Multibody decays are more nearly flavor symmetric
 - probably $G_0 \rightarrow \bar{q}qg > G_0 \rightarrow \bar{s}s$, since $\alpha_s > m_s/m_G$
- G_0 mixes predominantly with $\bar{s}s$, and even G_0 - $\bar{s}s$ mixing is suppressed $\Rightarrow G_0$ could be the purest glueball
- Favors **$G_0 = f_0(1710)$**
 - $m(G_0) \sim 1700$ from quenched LGT
 - $f_0(1710) \rightarrow \bar{K}K >> f_0(1710) \rightarrow \pi\pi$
 - $\psi \rightarrow \gamma f_0(1710) \rightarrow \gamma \bar{K}K$ BIG
 - Sticky $f_0(1710): f_2(1525): f_2(1270) = (>36):12:1$

Future:

- verify Weingarten LGT result with modern hardware/techniques
- further study of $f_0(1710)$ at BEPC and (maybe) CESR-C

LSP-Dark matter signal at CDMS & LHC

Nomura & Kitano
hep-ph/0509221
hep-ph/0509039

MSSM fine tuning problem: LEP $m_H > 114$

requires $m_{stop} \geq 1 \text{ TeV}$ $\delta m_H^2 \propto m_t^4 \ln(m_{stop}/m_t)$

creating fine tuning problem $\delta m_{H_u}^2 \simeq -\frac{3y_t^2}{4\pi^2} m_{\tilde{t}}^2 \ln\left(\frac{M_{mess}}{m_{\tilde{t}}}\right)$

in Higgs potential:

m_{stop}

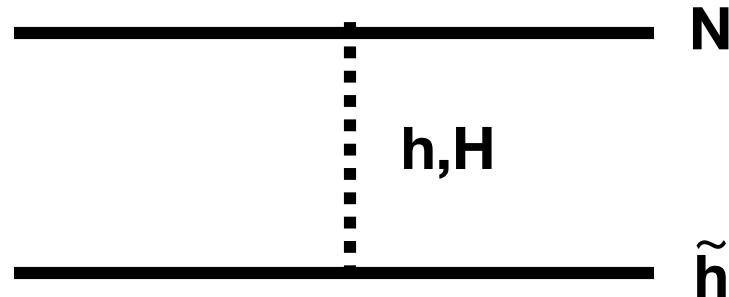
A natural solution: lower M_{mess} (anomaly + moduli SUSY breaking)

Universal gaugino spectrum $450 \leq M_0 \leq 900 \text{ GeV}$

Universal sfermion spectrum $M_{1/2} \sim M_0/\sqrt{2}$

LSP = Higgsino $m \sim 200 \text{ GeV}$ $\Omega \sim 0.2$

Dark matter signal at CDMS



$$\mu > 0 \Rightarrow + \text{interference} \Rightarrow \sigma \geq 10^{-44} \text{ cm}^2$$

$$\mu < 0 \Rightarrow - \text{interference} \Rightarrow \sigma \geq 10^{-47} \text{ cm}^2$$

$$b \rightarrow s\gamma \quad \begin{cases} \mu > 0 \Rightarrow - \text{interference} \Rightarrow \text{OK} \\ \mu < 0 \Rightarrow + \text{interference} \Rightarrow \text{too big} \end{cases}$$

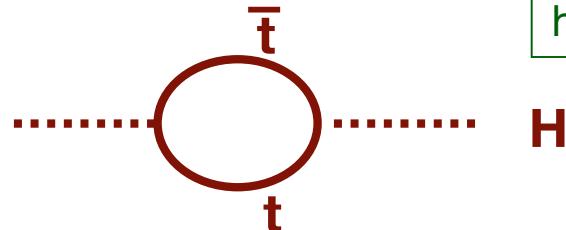


$\mu > 0$ favored, with assured signal at CDMSII.
Explication of underlying model at LHC.

Improved naturalness with unconventional Higgs sectors

Dangerous SM divergence:

$$\delta m_H^2 = (3/8\pi^2)y_t^2 \Lambda_t^2$$



Hall, Barbieri, Gregoire
hep-ph/0501243, 0509242

⇒ low cutoff for light H:

$$\Lambda_t \lesssim 400 \text{ GeV} \left(\frac{m_h}{115 \text{ GeV}} \right) D_t^{1/2}$$

where

$$D_t^{-1} \sim m_H^2 / \delta m_H^2 \sim \text{fine tuning}$$

→ **LEP Paradox:** why does SM fit EWRC so well if Λ_t is so low?

Q: Can Λ_t be pushed higher while keeping m_H small ?

A: Yes – by modifying Higgs sector, in ways observable at LHC

Two examples:

{ Mirror world
Two Higgs Doublet Model

A more natural two Higgs doublet model

Arrange $V(H_1, H_2)$ so that

$$\left\{ \begin{array}{l} H_1, H_2 \sim \text{eigenstates} \\ m_2/m_1 \sim 4 \\ t \text{ couples only to } H_2 - \text{discrete sym.} \\ \tan \beta = v_2/v_1 \sim 1/2 \end{array} \right.$$

- • H_1 dominates EWSB and is most strongly constrained by precision EW data but is not affected by top quark loop.
• EW data allows heavy $H_2 \Rightarrow$ larger Λ_t is natural.

$$\Lambda_t \lesssim 400 \text{ GeV} \left(\frac{m_h}{115 \text{ GeV}} \right) D_t^{1/2} \times \sin \beta (m_{95}/m_h)^{\frac{1}{\sin^2 \beta}}$$

For new $m_t = 172.7 \pm 2.9$, $m_{95} = 173$ (previously 285 for $m_t=178.0$)

⇒ For $\tan \beta = 1/2$, $D_t = 2$, $m_h = 120$, find $\Lambda_t \leq 1.6 \text{ TeV}$

(Or could raise Λ_t if $m_H \gg 115$ – what about precision EW constraint?)

Precision EW update for light top (no extra charge)

MC PRL 87:231802,2001
PRD 66:073002,2002

$$m_t = 178.0 \pm 4.3 \rightarrow 172.7 \pm 2.9 \quad \text{Run 2}$$

Global Fit $(\nu N, \Gamma_W)$	$\chi^2/n = 17.7/12$	$CL = 0.13$
	$m_H = 89$	$m_{95} = 173$
		$CL(m_H > 114) = 0.27$

Persistent 3.1 σ conflict: A_{FB}^b vs A_{LR} OR Hadronic vs Leptonic
Could be **statistics** or **new physics** or **systematic error**

If conflict due to
New Physics, can't
predict m_H until **NP**
is known.

Most likely culprits: A_{FB}^b , A_{FB}^c , Q_{FB}
⇒ exclude from fit
⇒ $\chi^2/n = 5.6/9$ $CL = 0.78$
⇒ $m_H = 48$ $m_{95} = 107$ $CL(m_H > 114) = 0.036$
⇒ **NP** needed to raise m_H above 114

Reading tea leaves:

13%: LEP Paradox & light Higgs @LHC

87%: possibilities wide open @LHC

Supplementary Material

- Partial list of former students from 1980
- Publications summary
- Awards/Honors/Service

Former students

(as best we know:
in some cases we
have lost touch)

Name	Advisor	Ph.D Year	Present Status
J. Polchinski	Mandelstam	1980	Faculty, UCSB
S. Moore	Mandelstam	1980	left field (medical school)
D. Friedan	Halpern	1980	Faculty, Rutgers U.
C. Flory	Suzuki	1981	Sr. Scientist (Hewlett Packard)
O. Kamayakcalan	Chew	1981	left field
P. deForcrand	Cahn	1982	Faculty, ETH Zurich
Y. Kang	Cahn	1982	left field
A. Axlerod	Hinchliffe	1982	left field (MIT computing)
M. Levinson	Chew	1982	left field (movies)
G. Batrouni	Halpern	1983	Faculty (U. Nice)
S. Sharpe	Chanowitz	1983	Faculty, (U. Washington Seattle)
V. Elser	Jackson	1984	Faculty, Cornell
M. Visser	Gaillard	1984	Faculty, (Washington U St Louis)
J. Carlson	Mandelstam	1985	Faculty, UCSF
Y-C. Kao	Suzuki	1985	Faculty, Taiwan
D. Issler	Chew	1985	left field
I.H. Lee	Gaillard	1985	postdoc (Rockefeller) left field
A. Smith	Mandelstam	1985	left field (software)
Z. Bern	Halpern	1986	Faculty, UCLA
S. Mahajan	Hinchliffe	1986	Faculty, U. Delhi
J. Manes	Zumino	1986	Faculty, Basque U. Spain
R. Ingermanson	Alvarez	1986	left field (software)
H. Chan	Halpern	1987	Faculty (UCSF)
O. Cheyette	Gaillard	1987	left field (finance)
D. Hwang	Zumino	1987	Faculty, Korea
L. Sadun	Halpern	1987	Texas A+M
J. Yamron	?	1987	left field (Dragon Systems)
N. Berkovits	Mandelstam	1988	Faculty (U. Sao Paolo)
M. Golden	Chanowitz	1988	Faculty (Harvard) and left field
V. Jain	Gaillard	1989	left field
D. Brahm	Hall	1990	left field (banking)
J. Burton	Gaillard	1990	left field
W. Schmidke	Zumino	1990	postdoc (York U.)
H. Veltman	Gaillard	1990	left field
T. Pritchett	Alvarez	1990	teaching position (Pomona St.)
M. Cleveland	Alvarez	1991	

Former students (2)

Name	Advisor	Ph.D Year	Present Status
G. Anderson	Hall	1991	Faculty (Northwestern) and left field
M. Berger	Chanowitz	1991	Faculty (U. Indiana)
M. Crescimanno	Bardakci	1991	Teaching position (Berea)
S. Hsu	Hall	1991	Faculty (Oregon)
N. Obers	Halpern	1991	Faculty (Niels Bohr Inst)
R. Zako	Alvarez	1992	left field (software)
S. Hotes	Bardacki	1992	teaching position (Case Western)
A. Berera	Mandelstam	1992	postdoc (Vanderbilt)
I. Otero	Alvarez	1992	Livermore Lab.
A. Papadopolous	Gaillard	1992	left field
K. Apfeldorf	Alvarez	1993	left field (software)
D. Pierce	Gaillard	1993	5-year (BNL), and left field
L. Yeh	Chew	1993	??
W. Taylor	Alvarez	1993	Faculty (MIT)
P. Schupp	Zumino	1993	Faculty (International U., Germany)
W. Kilgore	Chanowitz	1994	Senior Staff Physicist (BNL)
R. Lebed	Suzuki	1994	Faculty(Arizona State)
M. Austern	Cahn	1994	left field (software)
P. Watts	Zumino	1994	postdoc (Miami)
A. Rasin	Hall	1994	postdoc(Maryland)
R. Xiu	Gaillard	1994	left field
G. Keaton	Suzuki	1995	Postdoc -> Silicon Valley
T. Kaeding	Hinchliffe	1995	Postdoc
A. Antaramian	Hall	1995	left field
A.R. Elby	Chew	1995	left field
H Cheng	Hall	1996	postdoc(Harvard)
CS Chu	Zumino	1996	Faculty (Durham, UK)
PM Ho	Zumino	1996	Faculty (National Taiwan U.)
E. Holtmann	Gaillard	1996	Faculty (Los Medanos College)
N Arkani-Hamed	Hall	1997	Faculty (Harvard)
K Saririan	gaillard	1997	postdoc(Minnesota) deceased
Y-Y Wu	Gaillard	1997	postdoc (Hopkins) left field
H. Steinacker	Zumino	1997	postdoc (Munich)
K. Clubok	Halpern	1998	left field
K. Agashe	Suzuki	1999	postdoc (Johns Hopkins)

Former students (3)

Name	Advisor	Ph.D Year	Present Status
M. Graesser	Suzuki	1999	postdoc (Cal Tech)
A. de Gouvea	Murayama	1999	Faculty (Northwestern)
B. Morariu	Zumino	1999	postdoc (Rockefeller)
D. Brace	Zumino	2000	postdoc (Haifa)
A. Friedland	Murayama	2000	RP Feynman Fellow (LANL)
J. Evslin	Halpern	2002	postdoc (Brussels)
J. Wang	Halpern	2002	postdoc (Taiwan)
U. Vadarajan	Zumino	2003	postdoc (UT Austin)
A. Pierce	Murayama	2003	postdoc (SLAC)
C. Helfgott	Halpern	2004	postdoc (Tel Aviv)

Publications Summary

	<u>Journal*</u>	<u>Conf. Proc.</u>	
2002	82	6	
2003	64	10	
2004	70	6	(Through 10/04)
2005	58	6	(11/04 - 10/05)

List from 2005 + some of 2004 available online at review website

*Most published, some in process of submittal

Awards/Service (2002 -)

Aganagic: Sloan Foundation Fellowship, 2004

Gaillard: National Science Board, 1996 - 2002

Ligeti:

- DOE Outstanding Junior Investigator grant, FY 02
- US-Israel Binational Science Foundation grant, FY 02
- US-Japan Cooperative Science grant, 4/01 - 3/05
- Plenary speaker at ICHEP 2004, Beijing

Murayama

- Yukawa Commemoration Prize in Theoretical Physics, 2002
- Elected Fellow APS, 2003
- NRC Neutrino Facilities Assessment Comm., 2002
- Quantum Universe HEPAP subpanel, 2003 - 2004
- Fermilab PAC and KEK Lepton Collider PAC
- Concluding speaker at Lepton-Photon 2003, Fermilab
- Chair, DPF Education & Outreach Comm.

Nomura

- DOE Outstanding Junior Investigator grant, FY 04
- Sloan Foundation Fellowship, 2005

Zumino: 2005 Fermi Prize of the Italian Physical Society